

MOVEMENT ECOLOGY AND HABITAT USE OF RIO GRANDE WILD TURKEYS
IN THE TEXAS CROSS TIMBERS

A Thesis

by

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Submitted to the Office of Graduate and Professional Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

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December 2017

Major Subject: Wildlife and Fisheries Sciences

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ABSTRACT

Rio Grande wild turkey (*Meleagris gallopavo intermedia*) population dynamics (survival, reproduction) and habitat selection and use have been documented primarily within three ecoregions of Texas: 1) Edwards Plateau, 2) Rolling Plains and Panhandle, and 3) South Texas Plains. Little research has been conducted in north-central Texas within the Texas Cross Timbers ecoregion. Using advances in micro-GPS technology my focus was to determine wild turkey movements within a mixed-oak landscape. I focused on 1) identifying wild turkey demographics during the breeding season, i.e., nest success, nest rate, clutch size, nest site vegetation, and 2) evaluating hen movements during the pre-nesting period to determine if hens undergo habitat selection when choosing a nest site. Results from my research provide a better understanding of turkey movement and habitat use associated with varying life-history strategies, temporally and spatially.

ACKNOWLEDGEMENTS

I would like to thank the Texas Parks and Wildlife Department and personnel associate with the Upland Game Bird Stamp Fund, the Louisiana Department of Wildlife and Fisheries, the United States Department of Agriculture: Forest Service, and the Texas and Louisiana State Chapters of the National Wild Turkey Federation for providing funding and making this project possible. I would also like to thank the Texas State Chapter of NWTf for their generous support and guidance throughout my research. I am indebted to Mr. and Mrs. Terry and Ty Bartoskewitz of MT7 Ranch, the United States Department of Agriculture: Forest Service on the Kisatchie Ranger District, and J. Stafford for access, housing, and field logistical support. I greatly appreciate field support from Texas Parks and Wildlife District 3 personnel under direction of K. Mote and a host of private landowners for providing access to their properties. I also appreciate L. Scroggs, J. Wood, S. Johnston, L. Bennet and C. Boles for trapping assistance. I appreciate logistical support provided by the School of Renewable Natural Resources at Louisiana State University, the Warnell School of Forestry and Natural Resources at the University of Georgia, and Kevin Skow of the Institute of Renewable Natural Resources at Texas A&M University.

I would like to thank my committee, Dr. Michael J. Chamberlain of the University of Georgia, Dr. Bret Collier of Louisiana State University, Dr. Rusty Feagin of Texas A&M University, and Dr. Markus J. Peterson of the University of Texas at El Paso for their patience and guidance through this process. Within my committee, I

would like to especially thank Dr. Collier for taking a chance with me as his graduate student. The unaccountable hours spent in emails, calls, and field work with Dr. Collier have allowed me to appreciate how research should be conducted and how to act as a professional in all situations.

I also cannot thank Mike and Mary Terry and Ty Bartoskewitz and his family enough for their patience and graciousness during my time at the MT7 Ranch. It was their kind and inviting families that brought me back to Texas to begin this journey with Texas A&M University and eventually leading me to call Texas home. I will forever hold a special place in my heart for the MT7 Ranch, and I consider the Terry and Bartoskewitz families lifelong mentors and friends.

CONTRIBUTORS AND FUNDING SOURCES

Contributors

This work was supported by a thesis committee consisting of Professor Nova Silvy and Professor Bret Collier of the Department of Wildlife and Fisheries Science and Professor Russell Feagin of the Department of Ecosystem Science and Management.

The data analyzed and depicted in Chapters II and III was conducted in part by Bret Collier of the Department of Wildlife and Fisheries Science.

All other work conducted for the thesis was completed by the student independently.

Funding

Graduate study was supported by a research assistantship from Texas A&M University. This work was also funded by the Texas Parks and Wildlife Department Upland Game Bird Stamp Fund, the Louisiana Department of Wildlife and Fisheries, the United States Department of Agriculture: Forest Service, and the Texas and Louisiana State Chapters of the National Wild Turkey Federation.

NOMENCLATURE

TPWD	Texas Parks and Wildlife Department
RGWT	Rio Grande wild turkey
EWT	Eastern wild turkey
GPS	Global positioning system
VHF	Very high frequency

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CHAPTER I

INTRODUCTION AND LITERATURE REVIEW

Rio Grande wild turkeys (*M. g. intermedia*; hereafter, turkey), like many upland game birds, exhibit fluctuating population cycles. In Texas, research by Texas Parks and Wildlife (TPWD) in conjunction with Texas A&M University have focused on collecting population data within three of the eight ecoregions, including: 1) Edwards Plateau, 2) Rolling Plains and Texas Panhandle, and 3) South Texas Plains. However research on wild turkey population dynamics or habitat relationships within the Texas Cross Timbers is lacking. Understanding turkey demography and movement ecology during varying life-history strategies is imperative to directing sound management of the species. Recent advances in GPS technology have given us the ability to gather high-frequency locational data that has previously not been available for wild turkeys and other upland game birds. My work in the Cross Timbers ecoregion provides insight into how Rio Grande wild turkeys move in response to habitat conditions and reproductive phenology within a mixed-oak landscape.

Rio Grande wild turkeys (RGWT) are a sexually dimorphic species with males (toms) and females (hens) exhibiting morphological and behavioral differences. Males are larger in size, feathers appear more iridescent, and males have beards and spurs. Females are typically smaller in size, appear drab in color, and rarely produce beards or spurs. The Rio Grande wild turkey is similar in size and general appearance to other subspecies of wild turkey. Rio Grande wild turkeys will have a lighter, more buff coloration to the tips of the tail feathers and upper tail coverts than the dark brown of the

eastern subspecies and white of the western subspecies. Rio Grande wild turkeys are a mobile, nomadic bird that often shows strong fidelity to winter roost sites (Phillips et al. 2005, Byrne et al. 2015). Rio Grande wild turkeys will often congregate into large winter flocks and roost in the same group of trees for consecutive years (Thomas et al. 1966, Cook 1973.) Rio Grande wild turkey females will typically nest one to two times per year with a low nest-success rate (~17 - 32%), depending on environmental conditions (Collier et al. 2009, Dreibelbis et al. 2011, Locke et al. 2013). Movements between nests vary considerably but are typically less than the distance travelled for the initial nest (Locke et al. 2013).

Rio Grande wild turkey population dynamics and habitat relationships have been documented primarily within three ecoregions of Texas: 1) Edwards Plateau, 2) Rolling Plains and Panhandle, and 3) South Texas Plains (Dreibelbis et al. 2011, Melton et al. 2011, Locke et al. 2013). Little research has been conducted in north-central Texas within the Cross Timbers ecoregion. My research is in line with TPWD's efforts to restore and conserve nesting and brood-rearing habitat by outlining specifically what habitat conditions are required for successful nesting and reproduction within Texas. With the micro-GPS advance in technology (Guthrie et al. 2011), turkey biologists can now ask questions that before may have been biased with the use of previous telemetric protocol (Collier and Chamberlain 2011).

Turkey movement ecology is of significant interest to wildlife managers. Varying life-strategies (e.g., pre-nesting, nesting, brood-rearing) which occur at hourly, weekly, monthly, and seasonal scales may drive the selection of habitats and the

magnitude of movements of a female wild turkey. Movements also vary between and among the sexes as well as between age classes (Phillips et al. 2011). Traditional telemetry using very high frequency (VHF) transmitters requires the researcher to use a triangulation method (White and Garrott 1990) and is limited in the number of points estimated per day. Additionally, because the researcher must get within a reasonable distance to achieve an accurate location estimate, individuals may be disturbed or influenced by the researcher, biasing data on habitat use and movement. GPS transmitters eliminate bias associated with VHF triangulation and allow researchers to track animal movement trajectories and behavioral drivers (breeding movement, nest habitat search, nesting and brooding periods, loafing) to habitat selection, with the primary focus being development of habitat suitability models for turkeys in the Texas Cross Timbers.

My focus was on evaluating habitat selection by Rio Grande wild turkeys over the course of the breeding season, with specific attention paid to identifying pre-incubation habitat selection by nesting and brooding females. Considerable effort has been expended in the past to accurately quantify habitat selection of males and females over both the breeding (Badyaev et al. 1996, Chamberlain and Leopold 2000, Thogmartin 1999) and non-breeding/annual cycles (Holdstock et al. 2006, Hall et al. 2007). Underlying many previous works is the expectation that daily telemetry locations provide spatial location data at a resolution which is appropriate for identifying the spatial and temporal scale at which behavioral decisions are made. However, accurate estimation of habitat selection has relied on radio-telemetry approaches to measuring

spatial location. Using repeated telemetry locations over many days, range sizes and habitat selection were inferred. Using GPS units, I minimized potential error associated with radio-telemetry bias by basing inferences on high-resolution location data (Guthrie et al. 2011). Using the high resolution spatial data, I identified when shifts in habitat use occur in turkeys at multiple temporal frames (daily, weekly, monthly, seasonally; Byrne et al. 2015).

Information for identifying pre-incubation and post-hatching habitats is fairly limited in the ecological literature (Chamberlain and Leopold 2000). Reasons for the limited knowledge on pre-nesting movements of female RGWTs may be attributed to the amount of on-the-ground time necessary to account for habitat selected. Previous works state that female turkey movements should decline before nesting begins, and the rate of this decline should be directly proportional to the quality of the habitat available (Badyaev et al. 1996). Chamberlain and Leopold (2000) suggested that female movements increased during pre-incubation based on range and core area estimates. However, movement data used in these studies was based on traditional, telemetry based protocols which may bias predictions of turkey movements. From previous research, female movements are non-linear over time and space, thus the sampling interval of locational data is extremely important to predicting both movement rate and habitat selection during movements. Processes associated with female searching before nesting could cover a much wider variety of habitat than outlined by Chamberlain and Leopold (2000), yet still remain within a core use area, or cover a much smaller distance between movement distances and incubation. If female searching is occurring, then we should

observe a hierarchical selection of habitat based on pre-determined criteria of suitable versus non-suitable habitat (Jones 2001). Using the GPS units, I evaluated female turkey pre-nesting movement and built upon knowledge gathered from previous research.

CHAPTER II

INCUBATION MOVEMENT¹

II.1. Synopsis

Identifying demographic patterns is central to understanding wild turkey (*Meleagris gallopavo*) population dynamics and developing sound management strategies. Rio Grande wild turkey (*M. g. intermedia*; hereafter, turkey) populations in Texas exhibit considerable variability in population size annually, typically driven by pre-breeding season environmental events (e.g. precipitation) that create habitat conditions that drive nest success. However, it is unclear how turkeys use space during nesting, which may inform management actions. To better identify habitat characteristics and incubation-related movements and ranges of turkeys, I monitored females with GPS-VHF radiotransmitters on private and public lands in Stephens, Palo Pinto, and Wise counties within the Cross Timbers and Prairies region of Texas during spring and summer of 2012. I documented 46 nest attempts by 33 females and I recovered GPS data for 25 of these attempts. Overall, 24 females initiated a nest once, 8 renested, and 2 nested 3 times. Seventy-eight percent of nesting females used woody cover as nesting substrate, effectively avoiding warm season bunchgrasses common to my study areas. Mean incubation area range estimates (75 and 95% kernel) for incubating females were 1.64 (SE = 0.64) and 5.53 (SE = 4.32) ha. Recess movements

¹ Reprinted with permission from “Habitat selection, incubation, and incubation recess ranges of nesting female Rio Grande wild turkeys in Texas” by Mason D. Conley, J. G. Oetgen, J. Barrow, M. J. Chamberlain, K. L. Skow, and B. A. Collier, 2015. Proceedings of the National Wild Turkey Symposium, 11, 117 – 126, Copyright 2015 by Jason Burckhalter.

accounted for 72% (3.87 (SE = 3.94) ha) of 95% incubation range estimates. Females in my study consistently used areas with a heterogeneous spatial vegetative structure with few quantifiable differences that could be used to infer quality. My findings suggest that perhaps managers and researchers should reconsider how to define the scale at which females select nesting habitat, and how, or if, habitat-based measurements at the nest site provide specific information useful for management.

II.2. Introduction

Identifying drivers of reproductive success is central to furthering our understanding of wild turkey (*Meleagris gallopavo*; hereafter, turkey) population dynamics (Bowling et al. 2015, Byrne et al. 2015). Essential to our understanding of reproductive ecology of turkeys is identifying environmental and anthropogenic drivers thought to either support, or limit, reproductive output. For turkeys, nest failure remains the primary factor thought to limit population growth and sustainability (Pollentier et al. 2014), although the process of recruitment involves a suite of factors including hen success, nest success, poult survival, and juvenile survival (Melton et al. 2011). However, nesting success rates vary extensively (<10% to >90%), and are understood to be driven by interaction of predation (Melton et al. 2011), habitat (Badyaev and Faust 1996), and environmental conditions (Collier et al. 2009).

For ground nesting species like turkeys, it has been posited that small-scale habitat factors may mitigate against nest predation, increase nest success, and increase recruitment and populations (Chamberlain and Leopold 2000). Habitat selection and use by turkeys has been well documented (Miller et al. 1999, Thogmartin 1999), and

Chamberlain and Leopold (2000) suggested that examination of habitat at multiple scales is required to better link reproductive success to habitat type. However, most research on this topic relative to reproduction has been on pre-incubation habitat selection (Badyaev et al. 1996, Palmer et al. 1996, Chamberlain and Leopold 2000, Wilson et al. 2005) based on the assumption that pre-incubation movements are part of the nest site selection process.

Behavioral activities associated with laying eggs typically include the female laying 1 egg/day for 12-14 days, often skipping 1-2 days during the cycle (Healy 1992), and initiating incubation typically in the afternoon on the last day of laying. During the laying period, females generally spend most of their time away from nest sites, often exceeding distances of 3 km while only coming to nests to lay eggs (Healy 1992). Upon onset of incubation, female behavior adjusts as they remain at the nest site for 25-28 continuous days, and scale of inference for identifying ecological correlates for habitat selection is physically reduced to some proximal space around the nest site. The working assumption from both Badyaev et al. (1996) and Chamberlain and Leopold (2000) was that pre-incubation searching leads to selection of habitats types that increase likelihood of reproductive success (or reduce the likelihood of mortality), although Byrne et al. (2014) identified that pre-incubation searching may not occur. Working under the assumption that appropriate habitat conditions are limited and some form of selection occurs, we would expect to see habitat differentiation within incubation ranges for turkeys. In contrast, if habitats conditions are not limited, or if selection is not occurring, we should expect to see no habitat differentiation within an incubation range.

To better understand spatial scale at which turkeys are constrained during reproductive studies, my study focused on evaluating movements during the incubation of turkeys in north-central Texas. My objective was to examine incubation-related movements within estimated incubation ranges, identify general habitat metrics associated with both nest sites and incubation ranges, and describe generalities in habitat use of reproductively active female turkeys.

II.3. Study Area

I conducted research in the Cross Timbers ecoregion in north-central Texas. Within the Cross Timbers, I conducted work on 2 private ranches (MT7 Ranch and Strawn Field Site) in Stephens and Palo Pinto counties and the Lyndon B. Johnson National Grasslands in Wise County. These sites consisted of rolling hills and steep canyons, with elevation from 122-518 m above sea level (Gould 1962). The climate of the Cross Timbers was subtropical to semi-arid and temperature ranged from -19° C to 43°C with an average growing season of 237 days (Stahnke et al. 1980). Mean annual precipitation was 74.98 mm with rainfall away from the center of the ecoregion (Stahnke et al. 1980). The region was predominately rangeland with various species of bluestem (*Andropogon* spp.), grama (*Bouteloua* spp.), and panicum (*Panicum* spp.), with common overstory species including live oak (*Quercus virginiana*), ashe juniper (*Juniperus ashei*), post oak (*Quercus stellata*), black jack oak (*Quercus marilandica*), and mesquite (*Prosopis glandulosa*). Cedar elm (*Ulmus crassifolia*), pecan (*Carya illinoensis*), and cottonwood (*Populus deltoids*) were found along riparian areas. The Cross Timbers study sites were managed for white-tailed deer (*Odocoileus virginianus*) with other

management strategies focused on Rio Grande wild turkey and northern bobwhite (*Colinus virginianus*). Livestock grazing occurred on all study sites; however, a rotational grazing regime was implemented on 2 of the sites (Stephens and Wise counties).

II.4. Methods

I captured turkeys using drop nets (Glazner 1964) and/or walk-in traps (Davis 1994) baited with milo and corn. During January – March of 2012-2013, I marked each captured individual with a Texas Parks and Wildlife (TPWD) aluminum rivet leg band and fitted each with a VHF only or a combination GPS-VHF backpack-style radio (Sirtrack, Ltd., Havelock, New Zealand; Guthrie et al. 2011, Collier and Chamberlain 2011) with the GPS programmed to record at half-hour increments from 0600 to 2000 hrs daily. The Texas A&M University Institutional Animal Care and Use Committee (Permit 2010-287) approved capture and handling protocols. I monitored all radiotagged individuals via handheld radiotelemetry receivers (ATS R4000; Insanti, Minnesota, USA) approximately 3 times weekly before breeding season initiated based on female movement patterns (Melton et al. 2011). I located radiotagged females daily during nesting season (beginning approximately 15 March) so that nest location and initiation of incubation could be estimated using female movement patterns (Melton et al. 2011, Locke et al 2013). Upon suspected incubation, I visually located nests and continued to monitor females (from >100 m) until nests successfully hatched or females abandoned nests. I classified nest fates for analyses as apparent success (i.e., hatching of ≥ 1 egg) or failure (via female absence at the nest ≥ 2 days, egg remains or lack thereof, or

photographic evidence or predation or abandonment). After nest hatch/failure, I collected vegetation measurements for each nest site, including vegetation height (m), diameter (m) of nesting substrate, primary vegetation class (grasses, woody, or forbs) of nest sites, and primary nesting substrate (woody, grasses, forbs). For vegetation measurements, I used a 1.5-m tape measure to determine height at nest site center and diameter of nesting substrate. I used a densitometer at ground level on nest site centers to estimate canopy cover.

II.5. Data Analysis

I incorporated each nest location and movement data for each GPS-VHF tagged nesting female during the incubation period into an ArcGIS 10.2 (Environment Systems Research Institute, Redlands, CA) database. Based on daily individual movement trajectories for each female, I removed both first and last days of the incubation period to reduce spatial prediction bias caused by movements not associated with the incubation period. For example, females may roost >3km from nest sites in the morning, yet begin incubation that afternoon. For each female I calculated distance moved (m) from nest sites for each 30-minute interval each day. I used these data to estimate mean movement distance from the nests, both by day and for the entirety of the incubation period for each female during incubation. I excluded any GPS locations that were estimated within a minimum distance of 10 m from the nest site to account for errors in GPS accuracy, based on static tests in Texas in similar conditions, and to ensure that I was not biasing estimated movements low by including minor GPS location variation. Next, using all the GPS data for each female, I created a female-specific

incubation range derived from mean distance moved from the nest during each female's incubation period. I used Hawth's Tools in ArcMap 9.3 (Beyer 2004) to construct 50%, 75%, and 95% fixed kernels for GPS locations collected from each female during the incubation period. I used a scaling factor of 1000, a smoothing factor of 500, and an output raster size of 5 for kernel density estimation. As smoothing factors for simple kernel estimators are data dependent, I chose the smoothing factor based on biological knowledge of general turkey incubation movements as well as qualitative inspection of the density estimate. I created spatial polygons for each kernel and subtracted area of the 75% kernel from the 95% kernel and designated this value, which typically contained all locations that were not tied directly to the female being on the nest and hence being recess movements (movements typically associated with females leaving the immediate nest site for foraging, defecation, etc.), as recess movement area.

Additional to vegetation measurements collected at each nest site, I conducted a supervised classification at 1-m resolution using 2012 National Agriculture Imagery Program (NAIP) images to quantify vegetation communities within each incubation range into 2 vegetation classes: woody or grassland (Locke et al. 2013). Using this classification and treating each nesting attempt as an independent sample, I defined incubation habitat composition as percent of woodlands (with the inverse being the percentage of grassland) within female-specific incubation buffers. Weather conditions can influence nesting attempts, especially during drought periods (Collier et al. 2009), and were occurring during my study. However, based on my experience working in this

system, I assumed that if drought affects nesting activities, it was via increased movements during incubation tied to resource (food and water) acquisition.

II.6. Results

I captured and radio-marked 68 female wild turkeys during 2012 and 2013. I monitored 62 nesting attempts for both VHF and GPS tagged individuals. Thirty-three GPS-VHF radiotagged females attempted 46 nests, and I recovered GPS data for 25 nest attempts via female recapture or mortality events. Eleven VHF tagged females made 16 nesting attempts (Table 1). Apparent nest success was low in both 2012 (9.7%) and 2013 (6.5%), with only 3 successful nests (2 GPS-VHF, 1 VHF) in 2012 and 2 (2 GPS-VHF) in 2013 (Table 1). Hereafter, I focused only on GPS-VHF tagged individuals. Using GPS data, mean individual movements (meters from nest averaged across all days of incubation) varied from a minimum of 18.2 m to a maximum of 205 m (Table 2) with a mean average distance moved from the nest site for all females being 66.6 m (SE = 50.7; range = 18.2–205.8). Mean days of active incubation ranged from 1 to 25 with a mean of approximately 11 (SE = 8.5) days. Distribution of nest failures for GPS-VHF radiotagged females was bimodal, with 60% of failures occurring before incubation day 10 (Figure 1). Mean movement of females away from nests over the incubation period tended to decrease as incubation period lengthened and hatch date approached (Figure 2). Area of incubation movements (ha) corresponded to mean incubation movements (mean = 2.16; SD = 3.32; range = 0.10-13.29; Table 2). Females were specific in using primary nesting substrate (78% woody, 13% grasses, 9% forbs) and, whereas nests in woody vegetation tended to have a higher nest cover height, nest cover diameter was

qualitatively similar across nests sites (Table 3). Based on visual inspection of my results, average area used during incubation showed a general trend where 75% kernels were primarily incubation locations and 95% kernels incorporated the recess movements (Table 2, Figure 3).

II.7. Discussion

A significant amount of time and effort has focused on identifying the spatial scale at which habitat evaluations should occur for various periods of a turkey's seasonal activities. While much attention has been spent on seasonal ranges and pre-incubation periods (Chamberlain and Leopold 2000, Miller et al. 1999) and attempts to identify vegetation conditions associated with incubation (Badyaev and Faust 1996, Lehman et al. 2008), lack of an accurately defined incubation range has limited usefulness of these data for identifying habitat conditions associated with incubation. Nesting turkeys spend, when successful on their first nesting attempt, a minimum of 26 days tied to a single location; the area around this location is likely the most important habitat feature to a female during the year on a time ($1/12^{\text{th}}$ of their annual cycle) and effort (reproductive success) basis. My work provides the first measure of the appropriate scale of incubation habitat for Rio Grande turkeys in Texas (approximately 1.46 ha) at which managers should identify and evaluate habitat for turkey reproductive activities. Assuming a conservative annual range of a female turkey of 500 ha (Ramirez et al. 2012) and using the mean 95% kernel estimate of incubation range (5.33 ha), incubation-related habitats comprise approximately 1% of an individual's range. Hence, I suggest that while landscape-scale assessments of turkey habitat can be useful for generalizing

habitat conditions that turkeys are using (Glennon and Porter 1999, Thogmartin 1999), spatial scale at which these analyses are undertaken have been fairly arbitrary (Badyaev 1995, Miller et al. 1999, Fleming and Porter 2005, Goetz and Porter 2005) and unguided by actual bird space use (Collier and Chamberlain 2011). Thus, attempts to relate fine scale processes such as nest success to landscape features may be ineffective at separating biological processes from statistical inferences unless individual-based information is available and incorporated.

In general, my demographic results are comparable to previous Rio Grande wild turkey studies in Texas (Ransom et al. 1987, Randel et al. 2007, Melton et al. 2011, Dreibelbis et al. 2011, Locke et al. 2013), indicating that I may be identifying generalities in turkey nesting ecology. My estimates of nest success for this study were lower than the mean found by Locke et al. (2013), but were consistent with the common inter-annual variation in nest success found during wet and droughty years in Texas (Collier et al. 2009). I noted that the mean days of incubation from my study was slightly lower than found by Collier et al. (2009) in central Texas (15 days on average). Thus, my study, as did Locke et al. (2013), shows that there is consistent selection of general habitat conditions surrounding nest sites regardless of nest fate. Mean days of incubation in my study was slightly lower than found by Collier et al. (2009) in central Texas (15 days on average). However, Collier et al. (2009) noted that during 2007, there was significant precipitation and nearly a 100% nest initiation rate; great nest success is common during these periods (Locke et al. 2013), thus likely skewing that average slightly higher. Date of nest failure was distinctly bi-modal, wherein most (60%) nests

failed by incubation day 10. This implies that perhaps drivers of nest failure operate during the initial incubation period, but that if females are able to get past some threshold (tipping point), then the likelihood of nest success increases substantially. Not surprisingly, as incubation approached, female movements tended to decline. I did observe 2 peaks in daily mean movements for 2 females that each moved on one day >150m from nests when only 7 hens remained on nests, thus slightly skewing the mean. Interestingly, I noted that turkeys in my study were not entirely consistent with the current paradigms regarding daily excursions away from nests (Healy 1992). Females did adopt an on-the-nest/off-the-nest strategy, with some alternating every other day and venturing distances >100 m, whereas others moved off the nest on an irregular number of days and stayed within 30 m of the nest. However, most consistently stayed within 50-100m of nests and were rarely gone more than 1 hour (Figure 3). Similarly, in Georgia, Martin et al. (2015) found average recess times for hens, based on video surveillance, were 1 hr and 3 min.

Based on my results, 75% kernel incubation range estimates indicated that females primarily used an area of 1.46 ha during incubation. Although I was willing to accept a larger area with what I called incubation range using the 75% kernel versus a 50% kernel, what I identified as incubation habitat was typically much smaller than what I identified as recess habitat, or those areas where females moved to access food and water during incubation. At about 3.87 ha, recess movements and habitat types used during recess movements were likely overestimated relative to actual use, as standard kernel estimators do not account for linear movements (Byrne et al. 2014) typically

found as individuals move to and from water sources in my study area (unpublished data). I found little qualitative evidence for habitat selectivity at the incubation range scale across all turkeys, as no patterns were discernible to proportion of woody cover used (Table 3). However, similar to Locke et al. (2013), woody cover within incubation and recess movement areas was approximately 30% on average and nearly all females nested in sites dominated by woody cover (78%).

Behavioral decisions made by turkeys during incubation likely underlie population dynamics at the broader scale, and my results provide a relevant suite of results. Overall, it has long been assumed that the process of habitat selection occurs at various spatial scales and that any interpretation of scale selection is dependent on distribution of various habitat types. As stated by Collier and Chamberlain (2011), the scientific literature is replete with studies that document habitat use of turkeys to assist with management decisions. I have identified the scale at which habitat selection is occurring for incubating females on my study areas in north-central Texas, thereby expanding our knowledge of selection scale and processes for general habitat types important during incubation. Based on my work, I suggest that habitat management activities for nesting turkeys should consider additional focus on ensuring available usable space (Guthery 1997), as opposed to concerns about fine scale nest-site vegetation enhancements. Additionally, I propose that future habitat assessments that are focused on relating nesting success to habitat characteristics should be focused on an area <3 ha surrounding the nests in addition to nest site characteristics.

CHAPTER III

PRENEST HABITAT SELECTION²

III.1. Synopsis

Selection of habitats has regularly been suggested to influence species demography at both local and broad scales. The expectation is that selection behaviors have positive benefits via greater fitness or increased survival. The current paradigm of habitat selection theory suggests a hierarchical process, where an individual first selects where they choose to live (e.g., range) and then searches and selects locations within this range meeting life history needs. Using high frequency GPS data collected from reproductively active Rio Grande ($n = 21$) and Eastern ($n = 23$) wild turkeys, I evaluated a longstanding theory for ground nesting galliformes, in that movements during the pre-nesting period are behaviorally focused on sampling available habitats to optimize the selection of nesting sites. Contrary to expectations, I found no evidence that reproductively active females engage in habitat sampling activities. Although most nest sites (>80% for both subspecies) fell within the pre-nesting range, the average minimum daily distance from nest sites for Rio Grande and Eastern wild turkey females was large [1636.04 m (SE = 1523.96) and 1937.42 m (SE = 1267.84), respectively] whereas the average absolute minimum distance from the nest site for both Rio Grande and Eastern wild turkey females was 166.46 m (SE = 299.34) and 235.01 m (SE = 337.90),

² Reprinted with permission from “Do movement behaviors identify reproductive habitat sampling for wild turkeys?” by Mason D. Conley, N. A. Yeldell, M. J. Chamberlain, and B. A. Collier, 2016. *Ecology and Evolution*, 6(19), 7103 – 7112. Copyright 2016 by Mason D. Conley.

respectively and showed no clear temporal reduction as laying approached. Overall, predicted probability that any female movements before laying was initiated intersected with her nesting range (area used during incubation) was < 0.25 , indicating little evidence of habitat sampling. My results suggest that the long-standing assumption of hierarchical habitat selection by wild turkeys to identify nest sites may be incorrect. As such, habitat selection may not be the proximate driver of nest success and hence population-level fitness. Rather, based on my results I suggest that wild turkeys and other ground nesting species may be fairly plastic with regards to selection of reproductive habitats, which is appropriate given the stochasticity of the environments they inhabit.

III.2. Introduction

Patterns of habitat selection have long been suggested to influence species demography at both local and broad scales. In the simplest sense, habitat selection, or the process under which individual behavioral decisions drive use or non-use of particular habitat types, requires selection to have positive benefits to species demography via greater fitness or increased survival (Jones 2001). Selection is regularly posited as a hierarchical process, where an individual first selects where they choose to live (e.g., range) and then searches and selects locations within this range specific to demographic needs (Charnov 1976). As such, several authors (Orians & Wittenberger 1991, Badyaev et al. 1996, Jones 2001) have posited that selection of particular habitat types, specific to life history period, is important to population level demography. Adaptive site familiarity provides the foundation that behavioral decisions are driven by

familiarity with local conditions, which drives the habitat selection process (Maynard Smith & Parker 1976, Matthiopoulos et al. 2005). Hence, habitat selection theory suggests that decisions on habitat exploration or behavioral searching are primarily made based on features of the landscape, which individuals know or predict will confer positive demographic benefits. The standard expectation is that the longer an individual has to select and evaluate habitat, the more information can be garnered and used to identify optimal locations, such as those used for reproductive activities (Orians & Wittenberger 1991).

A primary driver of avian demography is reproduction, so the selection of nest sites has been of considerable interest (Clark & Shutler 1999, Jones 2001) as the primary limitation to nest success is predation (Sih et al. 1985, Clark & Shutler 1999). Identifying nest sites, to which most individuals will be tied for the duration of the reproductive period, should dominate all other components of habitat selection (Orians & Wittenberger 1991). Habitat sampling, or the process of individuals moving through their range and identifying conditions that should optimize demography, has been suggested to drive unbalanced selection of habitat types (Badyaev et al. 1996). Greater habitat sampling (reflected as area covered prior to nesting) should allow for acquisition and identification of optimal nesting locations. Optimal nesting locations, in turn, should improve safety during incubation under the assumption that habitat effects mediate predation of females or nests (Martin 1993).

Habitat selection by wild turkeys has been well documented (Miller et al. 1999, Thogmartin 1999), and both nest site characteristics (Seiss et al. 1990, Chamberlain &

Leopold 1998, Streich et al. 2015) and habitat characteristics within pre-nesting ranges (Badyaev et al. 1996, Chamberlain & Leopold 2000, Lehman et al. 2008) have been thoroughly described. Most literature suggests that nest-site vegetation characteristics provide structural cover that will impede or limit predation (Badyaev 1995, Fuller et al. 2013), although some evidence for reduction in foraging efficiency due to the number of potential locations which could be nest site locations, often denoted as unoccupied prey sites (Charnov 1976, Martin 1993) has been suggested (Chamberlain et al. 2003, Locke et al. 2013, Conley et al. 2015). Additionally, increased movements (e.g., habitat sampling) during the pre-nesting period has been purported to influence the selection of nest sites (Badyaev et al. 1996, Chamberlain & Leopold 2000, Lehman et al. 2008). For wild turkeys, most of this work has hinged on the process model outlined by Badyaev et al. (1996; also see Badyaev & Faust 1996), wherein wild turkey females select a nest site by narrowing down and selecting habitats using pre-determined criteria (e.g., site familiarity). If this assumption holds true, movements would narrow down as females evaluate and identify suitable versus non-suitable habitat, returning to areas of suitable habitats more frequently until a site is selected and the laying process begins. It is under this assumption that I am focusing my work, using movement behavior as a proxy to site selection as the mechanistic process of selection is unknown.

Habitat sampling, as outlined above, implies that females should select sites in advance of nesting activities and thus should have some ability to accurately predict site suitability in the future (Matthiopoulos et al. 2005). However, landscapes and vegetative conditions occupied by ground nesting birds are typically stochastic, regularly impacted

by anthropogenic factors such as prescribed fire and environmental factors such as drought/flooding or wildfire (Collier et al. 2009, Oetgen et al. 2015). Therefore, I propose that habitat sampling is unlikely for ground nesting birds with a reproductive period that requires between 30 and 40 days to successfully complete. Thus, I evaluated the theory of habitat sampling during the reproductive period using female wild turkeys as a model. I used high-frequency location data gathered throughout the breeding and nesting period to evaluate the relationship between pre-nesting ranges, movements, and nest site selection of Rio Grande and Eastern wild turkeys in north central Texas and central Louisiana, respectively.

III.3. Study Area

With the cooperation of the Louisiana Department of Wildlife and Fisheries and University of Georgia research assistant, Nathan Yeldell, I collected data on Eastern wild turkeys (*Meleagris gallopavo silvestris*) on the Kisatchie National Forest (hereafter KNF) on the Kisatchie and Winn Ranger Districts in west-central Louisiana, USA from January to July 2014. The Kisatchie District was comprised of 41,278 ha in Natchitoches Parish, whereas the Winn District comprises of 66,368 ha in Winn, Natchitoches, and Grant Parishes. Topography was rolling upland hills, high ridges, and sandy creek bottoms. The KNF was primarily composed of pine dominant forests, mixed pine-hardwood forests, and hardwood dominant streams and drains; forest openings, utility right-of-ways, and forest roads were found throughout both ranger districts. Overstory trees included loblolly pine (*Pinus taeda*), shortleaf pine (*P. echinata*), longleaf pine (*P. palustris*), slash pine (*P. elliottii*), sweetgum (*Liquidambar styraciflua*), southern red oak

(*Quercus falcata*), blackjack oak (*Q. marilandica*), post oak (*Q. stellata*), hickories (*Carya* spp.) and sweetbay (*Magnolia virginiana*). Understory plants included yaupon (*Ilex vomitoria*), American beautyberry (*Callicarpa americana*), broomsedge (*Andropogon virginicus*), panic grasses (*Panicum* spp. and *Dichanthelium* spp.), woodoats (*Chasmanthium laxum*), and brackenfern (*Pteridium aquilinum*). The US Forest Service typically conducted prescribed burns (both dormant and growing season) ranging in size from 7 to 1566 ha (18-22% of the available landscape) from December into May.

I collected data on Rio Grande wild turkeys (*Meleagris gallopavo intermedia*) from January 2012-August 2014 in the Cross Timbers ecoregion in north-central Texas, USA. Within the Cross Timbers, I conducted work on private properties in Stephens and Palo Pinto counties and the Lyndon B. Johnson National Grasslands in Wise County. These sites consisted of rolling hills and steep canyons, with elevation from 122 m to 518 m above sea level (Gould 1962). The region was predominately rangeland with various species of bluestem (*Andropogon* spp.), grama (*Bouteloua* spp.), and panicum (*Panicum* spp.), with common overstory species including live oak (*Quercus virginiana*), ashe juniper (*Juniperus ashei*), post oak (*Quercus stellata*), black jack oak (*Quercus marilandica*), and mesquite (*Prosopis glandulosa*). Cedar elm (*Ulmus crassifolia*), pecan (*Carya illinoensis*), and cottonwood (*Populus deltoids*) were found along riparian areas. Study sites were managed for white-tailed deer (*Odocoileus virginianus*) with other management strategies focused on Rio Grande wild turkey and northern bobwhite (*Colinus virginianus*).

III.4. Capture and Monitoring

I captured turkeys at baited sites using rocket nets (Dill 1969), drop nets (Glazener et al. 1964) and/or walk-in traps (Davis 1994). All captured individuals were aged, sexed and marked with an aluminum rivet leg band and fitted with a GPS-VHF backpack-style radio transmitter (Biotrack Limited, Wareham, UK) with the GPS programmed to record at 1 hour increments from 0600 to 2000 daily with one location at midnight to identify roost site location. Capture and handling protocols were approved by the Texas A&M University Institutional Animal Care and Use Committee (Permit 2010-287) and the University of Georgia Institutional Animal Care and Use Committee (Permit A2013 12-002-Y1-A0). I monitored all radio-tagged individuals via radio-telemetry weekly before the breeding season. I located radio-tagged females > 4 times weekly during the nesting season (beginning approximately 15 March) so that nest location and initiation of incubation could be approximated by female movement patterns (Chamberlain and Leopold 2000, Collier et al. 2009). Upon suspected incubation, I located the general area of each nest site and continued to monitor the nesting female without disturbing the nest until nest success, failure, or abandonment. I classified nest fates for analysis as apparent success (i.e., hatching of ≥ 1 egg) or failure (via female absence at the nest ≥ 2 days, egg remains or lack thereof).

III.5. Statistical Analysis

I incorporated each nest location and resultant movement data for each female during the pre-nesting, laying, and incubation period into ArcGIS 10.2 (Environment Systems Research Institute, Redlands, CA) database. I defined the pre-nesting period as

the 45 days before the first record of an individual initiating a nest (Chamberlain & Leopold 2000). I defined the laying period based on hourly GPS movement data as the period during which the female made daily trips to the nest site for the purpose of laying, but typically roosted elsewhere in the immediate area (Collier & Chamberlain 2011). I defined the incubation period as beginning on the day the female approached the nest and all subsequent GPS locations were within a 50 m buffer around the nest site for that day as found by Conley et al. (2015). Note I also cross-validated the above delineations using my regular radio-tracking data.

The theory of habitat sampling, and hence nest site selection, is founded on the expectation that the outcome of sampling and the selection process has demographic consequences (Jones 2001). My work was not focused on demographic consequences of selection, but rather on whether the behavioral process of sampling was occurring, and whether that process could be identified based on movement information. Thus, first for each female I calculated a pre-nesting range (50, 95, 99% kernels) based on GPS locations collected during the 45 days prior to incubation initiation using a dynamic Brownian bridge utilization distribution estimator (Kranstuber et al. 2012). Using the pre-nesting ranges, I evaluated whether or not a nest site location was within the associated core area (50% kernel), the typical estimate of a species range (95% kernel) and what I considered a maximum area of use by each individual (99% kernel). Next, for each female I calculated the distance to each individual GPS location from the nest site each day and estimated the mean and minimum distance from the nest for all locations, by day, and for the entirety of the incubation period. Based on Guthrie et al.

(2011), I excluded any GPS location that was estimated within a minimum distance of 10 m from the nest site to account for errors in GPS accuracy. This exclusion ensured I was not artificially biasing estimated movements low by including variation attributable to GPS location error when females were likely stationary while incubating their nests. I then used Hawth's Tools in ArcMap 9.3 (Beyer 2004) to construct 50%, 75%, and 99% fixed kernels for GPS locations collected from each female during the incubation period (Conley et al. 2015) and created individual-specific, nest-associated buffers of 1) 95% fixed kernel for the female's incubation range with a radius equating to the area of the kernel, 2) a 75% fixed kernel, 3) the mean distance from the nest site for all GPS location collected during incubation, respectively, during incubation based on all females (RGWT: 70.82 m, EWT: 55.24 m) and 4) 100 and 500 m buffers around each nest site (Conley et al. 2015, Figs 1 & 2). Using these buffers, I documented the frequency and distance for each hourly movement segment (connected linear path between 2 consecutive GPS locations) of the female's daily movement paths that intersected the boundary of each buffer described above for the 45 days before the female began laying (Tables 5 and 6). I classified each hourly path segment as either intersected (1) or non-intersected (0) and used logistic regression to model the probability that a female's movement path intersected the area (defined above) around the nest site location as a function of time (day) for each of the 45 days preceding the female laying her first egg and initiating a nest (Figures 4 and 5). I then used contingency table analysis to evaluate the odds of a female turkey having locations within the nest site buffer (smallest possible area detailed above) by comparing the

frequency of locations 0-5 days before the female began laying to frequency of locations 6-15 days before laying, and then 6-15 days to 15-45 days before laying began. I conducted all statistical analysis in R v3.1.3 (R Development Core Team 2015).

III.6. Results

I captured and GPS radio-marked 21 Rio Grande and 23 Eastern wild turkeys during 2012–2014. The average number of days with available movement data during pre-nesting for Rio Grande and Eastern females was 42.38 (SE = 5.21; range = 25 – 46) and 45.04 (SE = 0.21), respectively and was dependent on the date captured relative to when laying began. For example, for a transmitter programmed to begin March 15, if a female began laying on April 15, then 30 days of pre-nesting movements would be available (Tables 5 and 6). Average daily distance of all locations from a nest site for Rio Grande and Eastern wild turkey females was 1636.04 m (SE = 1523.96) and 1937.42 m (SE = 1267.84), respectively, whereas average minimum distance of all locations from the nest site was 166.46 m (SE = 299.34) and 235.01 m (SE = 337.90), respectively (Tables 5 and 6). Most female Rio Grande (81%) and Eastern (87%) wild turkeys did not have nest sites within their core (50%) pre-nesting ranges, but most (85% RGWT and 82% EWT) fell within their 99% ranges (Tables 5 and 6).

During the 45 day pre-nesting period, 3 Rio Grande females (14%) were closest to their nest between days 16 – 45, 4 (19%) between days 6 – 15, and 14 (67%) between days 1 – 5 (mean = day 8; range = 33 – 1). For the 67% of Rio Grande females that had their minimum distance to the nest within ≤ 5 days before laying initiated, the average distance from the nest site was 210 m which increased during the ≤ 2 day period slightly

to 213 m ($t = -0.012$, $df = 12.2$, $p = 0.9899$). The odds that a Rio Grande wild turkey female was located within the nest buffer during 1 – 5 days before laying was 2.9 (95% CI: 1.27 – 6.90) times the estimated odds of being located within their individual nest buffer during the 6 – 15 day period. Odds of being located within the individual nest buffer 6 – 15 days before laying were 4.9 (95% CI: 1.85 – 13.88) times the estimated odds of being located within the nest buffer during the 16 - 45 day period. For the 45 day pre-nesting period, 5 Eastern females (22%) were closest to their nest between days 16 – 45, 5 (22%) between days 6 – 15, and 13 (56%) between days 1 – 5 (mean = day 12; range = 44 – 1). For the 56% of Eastern wild turkey females that had their minimum distance to the nest within ≤ 5 days before laying initiated, the average distance from the nest site was 197 m which increased during the ≤ 2 day period to 402 m ($t = -1.06$, $df = 12.1$, $p = 0.3089$). The odds that an Eastern wild turkey female was located within the individual nest buffer during 1 – 5 days before laying were 5.2 (95% CI: 1.65 – 19.40) times the estimated odds of being located within the individual nest buffer during the 6 – 15 day period. Odds of being located within the nest buffer 6 – 15 days before laying were 1.13 (95% CI: 0.31 – 3.43) times the estimated odds of being located within the nest buffer during the 16 – 45 day period.

Both Rio Grande and Eastern wild turkey females had a greater probability ($\beta_{\text{daysprenesting}} = -0.06$ and -0.03 ; $p < 0.001$) of their daily movements during pre-nesting intersecting with the largest of the nest area buffers, which increased as the first day of laying approached (500m; Figs 3 & 4). The probability that a female was within 100 m of the nest site was predicted to be highest on the day before laying began ($\beta_{\text{daysprenesting}} =$

-0.09 and -0.05; $p < 0.001$), yet was < 0.25 for both subspecies. The estimated probability of intersection for all buffers approached zero as number of days before nest initiation increased. Likewise, the probability ($\beta_{\text{daysprenesting}} = -0.09$ and -0.04 ; $p < 0.001$) that a female moved within the nest incubation range (75% kernel for incubation period) was < 0.20 for both subspecies (Figs 6 & 7).

III.7. Discussion

Habitat selection is the process of behavioral responses that may result in the disproportionate use of areas that influence survival and fitness of individuals (Block & Brennan 1993, Jones 2001). Badyaev et al. (1996) suggested that selection would be manifested via 1) habitat sampling during the pre-nesting period allowing for selection of a better nest site, and 2) that selection should favor extended sampling by individuals, with 3) greater dispersal by higher-fitness individuals being correlated with finding better quality sites early in the season, and 4) that the extent of habitat sampling early in the season also influenced reproductive performance by impacting renesting (see Jones 2001). My findings suggest that the above assumptions and inferences that hinge on the basis that wild turkeys sample habitat before nesting as detailed by Badyaev et al. (1996) above may be erroneous. Hence, although the theoretical foundation has been that individuals should select habitat, and hence nest sites, that maximize reproductive success (Wiens 1989, Martin 1993, Jones 2001), I suggest that any demographic benefits may in fact not be driven by a habitat selection process, at least for wild turkeys. Based on my results, I suggest that the assumption of habitat sampling for nest site selection as purported by Badyaev et al. (1996) is incorrect.

My focus was to determine if habitat sampling was occurring during the period prior to nest initiation when turkeys have been assumed to be sampling (Badyaev et al. 1996, Chamberlain & Leopold 2000, Jones 2001, Collier and Chamberlain 2011). More than half (67% and 56%) of Rio Grande and Eastern wild turkey females, respectively, were closest to their future nest site ≤ 5 days before laying, and odds of being within the individual nest site buffer increased as nest initiation approached. Hence, if there is an appropriate temporal scale associated with the pre-nesting period it should be tied to movements during the period immediately before laying, ≤ 5 or more likely ≤ 2 days. However, average minimum distances from each location to the nest site during pre-nesting exceeded 150 m (166 and 235 m for RGWT and EWT, respectively) and most females did not get within a minimum of 50 m from their nest site before the first egg was laid. Hence, it appears that most females do not sample areas within their ranges searching for specific nest sites before laying (Badyaev et al. 1996). I offer that a distance of 166 or 235 m away from eventual nest sites would encompass a wide variety of habitats and conditions in most systems, and is well outside the typical extent of area estimated as used (1.46 ha) by incubating females (Conley et al. 2015).

I recognize that wild turkeys could have sampled habitats outside of my monitoring period, perhaps during the wintering period preceding the nesting season. For example, the habitat sampling paradigm outlined by Badyaev et al. (1996) suggested that females choose a nest site before they choose a mate, hence the amount of nesting habitat sampled is reflected by the extent of each female's movements and amount of area covered before initiating a nest. My findings suggest this paradigm may be

biologically implausible. Given the stochastic environment in which turkeys exist, the expectation that habitat or other environmentally driven conditions would be static over a time period of up to or exceeding 2 months is highly uncertain. For instance, my sample of Eastern wild turkeys existed on a landscape managed with extensive use (32,602 ha) of prescribed fires during the reproductive season (18-22% of the available landscape). Likewise, my sample of Rio Grande wild turkeys existed on a landscape driven by a drought-precipitation cycle occurring typically in March and April (Collier et al. 2009) with the bulk of nesting occurring in April through June (Melton et al. 2011). More importantly, my results provide no evidence that females search for and locate sites where their future nests occur during the pre-nesting period, as suggested by Badyaev et al. (1996) and Chamberlain & Leopold (2000). Within this vein, I acknowledge that there could be an experience aspect not evaluated here to nest site selection (Hoi et al. 2012), wherein individuals that nested in a particular location return to that location if successful in the preceding year. Potentially, my results could be impacted by memory, wherein individuals who previously have nested would have a memory of successful/unsuccessful locations. However, Locke et al. (2013) found for 194 Rio Grande wild turkey nesting attempts that distance between nest locations both within and between years were typically separated by over 1,000 m and was unrelated to nest success or failure, I suggest that wild turkeys have low fidelity to nest locations, independent of previous demographic result, and thus memory is likely inconsequential.

Predation is the leading cause of mortality for most ground-nesting birds (Chalfoun et al. 2002, Stephens et al. 2005), including wild turkeys (Miller et al. 1999).

Predation risk can influence various aspects of bird behavior (Lima 2009), including fine-scale foraging behavior (Suhonen 1993) and broader patterns of habitat use (Rodriguez et al. 2001). I recognize that predation risk could influence behavior of female wild turkeys during pre-nesting periods, as females may select habitats within their ranges to minimize risk of predation. If this occurred, then predation risk could have influenced my observations of female behavior prior to nest initiation. However, adequately assessing this potential was outside the scope of my work, as no accurate estimates of predator abundance or distribution existed on my study sites, and I lacked information detailing predator behavior as well. Regardless, female wild turkeys monitored in my study existed on 2 landscapes with relevant differences in vegetation, productivity, and community structure (Ames et al. 2016), hence one would expect predation pressure to be variable across sites (Chalfoun et al. 2002). Because I observed similar behaviors across females in my study, I offer that predation risk is not likely the most important driver of female behavior during the period prior to nesting.

One area of continued interest in wildlife resource selection revolves around defining the appropriate scale of habitat selection (Orians & Wittenberger 1991). For wild turkeys, I suggest that evaluations of habitat selection should be redefined to the period immediately before nesting, as opposed to the ≥ 45 day period previously defined by Chamberlain & Leopold (2000). Unfortunately, this time frame somewhat negates the basis of habitat sampling theory and use-availability models to identify or distinguish selection based on deviations in habitat use between nesting and non-nesting locations over time. Those methods, in theory, require some sort of sampling to occur. According

to the definition provided by Jones (2001), the lack of hierarchical habitat selection, and the low probability that a wild turkey female uses areas within her eventual incubation range (Conley et al. 2015), suggest that perhaps nest site selection is a random event based on the physiological status of a reproductively capable individual rather than a process being driven by some underlying sampling regime.

CHAPTER IV

CONCLUSION AND MANAGEMENT IMPLICATIONS

IV.1. Conclusion

Wild turkey population exhibit fluctuations due to a wide variety of factors (Collier et al. 2009) and as such factors attributing to the decline of the species should be mitigated against with land managers being vital in supporting the fitness and survival of the species. Focusing on available habitat and promoting usable space (Guthery 2007) should be the primary task as land managers and researchers focus on prolonging wild turkeys for future generations.

Previous studies have evaluated turkey ranges throughout various life-history strategies (Badyaev 1995, Badyaev et al. 1996, Bowling et al. 2015, Byrne et al. 2015, Chamberlain and Leopold 2000, Collier et al. 2009, Conley et al. 2015, Fleming and Porter 2005, Fuller et al. 2013, Glennon and Porter, 1999, Goetz and Porter 2005, Locke et al. 2013, Melton et al. 2011, Miller et al. 1999, Palmer et al. 1996, Pollentier et al. 2014, Randel et al. 2007, Ransom et al. 1987, Ramirez et al. 2012, Seiss et al. 1990, Streich et al. 2015, Thogmartin 1999, Wilson et al 2005). While we oftentimes aggregate breeding season movements into one range, several movements and associated ranges within the breeding season should be noted. When considering selection on a temporal scale, range size and structure vary according to each life-history strategy. Previous studies have focused on defining seasonal and pre-nesting ranges (Chamberlain and Leopold 2000, Miller et al. 1999), but little to no research has been conducted on actual incubation range and habitat requirements within an incubation range. My

research offers the first estimate of the incubation range (~1.46 ha) required for female Rio Grande wild turkeys. Within the incubation range, each individual must find enough forage, water, and cover to sustain the female during the 26 day incubation period, with the added complexity of remaining undetected by potential predators. The incubation range represents the most important area for a female turkey during the annual cycle as females are tied to the nest site and hence the incubation range for the duration of the nesting period. Identifying this range provides us with a better understanding of female turkey ecology and allows us to identify the ecological correlates associated with this spatial area for further use in turkey habitat management. With the understanding that movement is limited and each movement during incubation is important for the female's health, and subsequently the brood, land managers now have a scale to reference what the patch-like matrix of habitats should resemble.

My demographic results are in line with previous turkey literature in Texas and further support the established knowledge of nesting ecology of RGWT (Ransom et al. 1987, Randel et al. 2007, Melton et al. 2011, Dreibelbis et al. 2011, Locke et al. 2013). Consistent with Locke et al. (2013), female turkeys used areas with 30% woody vegetation for nest sites, and additionally I found that females used areas with approximately 78% woody cover for incubation ranges and recess movements. A moderately-woody grassland landscape, likely fire maintained within the Cross Timbers region of Texas with at least 30% woody vegetation should provide enough edge to facilitate movement as well as provide adequate foraging opportunity.

My work found that incubating females exhibited inconsistent on/off nest strategies, with some movements occurring daily while others may move infrequently over a 3-5 day period. A few females frequently ventured >100 m from the nest while most remained within 30 m to return within the hour and continue incubation. Recess movements, or movements outside the incubation range (1.46 ha) to find water or forage regularly occurred and increase the nesting range to approximately 3.46 ha (95% UD).

Before nest initiation begins, the established theory was that wild turkey females will select a nest site from previously sampled habitat and return to that nest site prior to laying (Badyaev et al. 1996). With this theory comes the expectation that there is a hierarchical process of selecting suitable versus unsuitable habitat for a nest site (Jones 2001). Time spent on selection of an optimal nest site should improve fitness and survival of the species as a beneficial life-history strategy. My results found that habitat sampling is limited and that the scale of habitat sampling should be reconsidered. I conducted research on both Rio Grande wild turkeys and Eastern wild turkeys to determine if habitat selection, or its extent, was subspecies-limited. However more than half (67% and 56%) of Rio Grande and Eastern wild turkey females, respectively, were the closest to their future nest site ≤ 5 days before laying. Hence, if there is an appropriate temporal scale associated with the pre-nesting period, then it should be tied to movements during the period immediately before laying.

My results provide a wide array of traditional wild turkey data coupled with challenging the previous concept of scale of habitat selection among female turkeys during the pre-nesting period. As land managers and researchers we are tasked with the

duty of prolonging the species through sound research and habitat management. My results provide an appropriate scale for land managers to consider when evaluating land use from a turkey's perspective. The lack of selective activities thus enforces the notion that providing sufficient usable space within the overall landscape should be the primary goal for land managers. Regretfully, my research indicates that there is likely no single or set of habitat conditions that are primarily selected for by Rio Grande wild turkey females during the nesting season. Rather, my research indicates, at best, that the selection process is likely extremely short and shows no affinity toward any particular conditions. This lack of affinity should not be surprising as wild turkeys are abject generalists that exist in a wide variety of conditions and locations across the United States, and such should be fairly plastic in their habitat needs.

As it is unlikely we will be able to manage particular sites at the fine scale, management activities should be focused on providing necessary requirements (cover, forage, water, and roosting areas) distributed as uniformly as possible across the landscape. At the landscape scale, a matrix of habitats which encompasses all physiological requirements would include management for well interspersed grasslands with woody vegetation at different successional stages making up at minimum 30% of the landscape. This would ensure adequate habitat substrate for individual nesting locations use and may also facilitate movement throughout the landscape and/or reduce predation risk.

Partnerships among private landowners, state and federal agencies, non-government organizations, and universities continue to drive research of wild turkey

ecology and management. With the majority of Texas being privately owned and the increase in land fragmentation, the survival of the species is reliant on landowner partnership, education, and the willingness to implement beneficial management practices at the landscape level.

IV.2. Management Implications

My results confirm that during the incubation period, the utilized area for Rio Grande wild turkey females is limited and that outside of a few moderate (<300 m) excursions, females are restricted to an immediate (1.46 ha) area around nest sites. As the area around nest sites must provide all necessary resources for nesting females and likely mitigates against predation, I suggest that future work focuses on identifying incubation range habitat characteristics to further our understanding of nesting ecology.

My results also confirm that female wild turkeys are not searching for a nest site based on a predetermined criteria before nest initiation occurs. As selecting an optimal nest site may decrease predation and thus increase fitness and survival, I suggest that any evaluation of nest site selection be redefined to ≤ 5 days prior to nest initiation and perhaps further research should focus on the physiological status at the individual level versus any habitat sampling regime.

At the landscape level, land managers should focus on providing enough forage, water, and cover within a matrix of habitats to provide for usable space for incubating females. Like many upland species, wild turkeys are an edge species and providing additional edge habitats in a larger grassland matrix should be of primary focus for nesting and brooding habitats. Edge habitats can be accomplished by brush

management, disked strips, prescribed fire, etc., such that the landscape may provide travel corridors, increase forage opportunity, grant access to suitable nesting substrate, and provide other components required by wild turkeys.

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APPENDIX

Study Site		2012		2013	
		Initial	Renest	Initial	Renest
MT7	GPS	4	2	10	3
	VHF	7	3	2	1
Strawn	GPS	6	3	5	0
	VHF	0	0	0	0
LBJ	GPS	4	2	4	3
Grassland					
	VHF	0	0	2	1

Table 1. Initial and renesting nesting frequencies by radio-transmitter type (GPS-VHF [GPS] and VHF) and study sites for radiotagged female Rio Grande wild turkeys in north-central Texas during 2012 and 2013.

Vegetation	2012	2013
Woody	22	27
Forbs	3	1
Grass	6	3
Fate		
Successful	3 (9.68%)	2 (6.45%)
Failed	28	29
Total	31 (26)	31 (42)

Table 2. Vegetation class selected and fate of Rio Grande wild turkey nests (total females tracked) in north-central Texas, USA during 2012 and 2013.

Band ID	Days of Incubation	Mean incubation movement (meters from nest) (SE)	Mean incubation movement area (ha)	Proportion Woody Cover ¹ 50%	Proportion Woody Cover ¹ 75%	Proportion Woody Cover ¹ 95%	50% (ha)	75% (ha)	95% (ha)	95% Recess (ha)
8058(1)	9	21.41 (6.24)	0.14	14.18	11.70	10.77	0.59	1.19	2.69	1.50
8058(2)	18	51.20 (24.75)	0.82	26.66	34.30	36.17	0.66	1.42	5.01	3.59
A590	2	205.76 (125.56)	13.29	22.20	21.50	17.06	1.48	4.37	14.03	9.65
21270	19	47.39 (82.81)	0.70	15.92	13.77	9.94	0.57	1.15	2.75	1.59
8009	14	77.97 (53.01)	1.91	76.07	71.68	57.20	0.65	1.39	6.30	4.91
8013(1)	7	30.04 (5.19)	0.28	55.61	59.16	62.76	0.56	1.14	2.68	1.54
8013(2)	5	136.28 (131.52)	5.83	2.22	1.59	29.40	0.75	1.85	13.55	11.69
8013(3)	24	85.96 (91.60)	2.32	4.90	4.49	4.03	0.61	1.26	4.30	3.03
8016	2	37.35 (1.32)	0.44	42.32	38.44	32.52	0.63	1.28	2.98	1.70
8021	9	35.74 (16.91)	0.40	19.05	20.85	23.12	0.61	1.25	3.24	1.99
8024	10	73.51 (95.63)	1.69	10.00	9.30	22.59	0.63	1.37	6.00	4.63
8026	10	89.92 (63.11)	2.54	45.25	50.45	37.74	0.66	1.44	7.19	5.74
8028	7	169.70 (89.75)	9.04	5.94	5.51	20.09	0.73	1.84	19.89	18.05
8029	4	18.20 (1.51)	0.10	44.93	45.94	42.79	0.58	1.17	2.57	1.40
8061(1)	1	26.06	0.21	69.56	63.89	58.98	0.61	1.24	2.71	1.46
8061(2)	1	79.45	1.98	44.72	47.22	40.78	0.68	1.52	4.41	2.89
8063(1)	4	39.04 (30.20)	0.48	47.54	37.03	21.36	0.67	1.39	3.57	2.19
8063(2)	4	66.48 (52.39)	1.38	18.61	16.74	15.03	0.60	1.25	3.71	2.46
8503	22	40.83 (41.14)	0.52	30.62	29.77	29.83	0.60	1.25	3.25	2.00
A588	25	31.24 (15.42)	0.31	41.20	42.85	45.34	0.61	1.25	3.25	2.00
A589(1)	23	38.75 (36.68)	0.47	44.08	42.12	33.68	0.60	1.24	3.06	1.83
A589(2)	8	158.30 (89.04)	7.87	8.14	6.58	8.29	0.69	1.58	7.23	5.65
A589(3)	3	20.89 (13.42)	0.14	17.77	21.01	20.02	0.56	1.16	2.75	1.58
A591	23	57.87 (88.67)	1.05	33.94	39.30	40.13	0.59	1.20	3.16	1.96
A587	24	24.49 (7.43)	0.19	24.14	23.83	23.28	0.62	1.29	2.99	1.70
Mean (SE)	11.12 (8.48)	66.55 (50.70)	2.16 (3.32)	30.62 (20.02)	30.36 (19.71)	29.72 (15.96)	0.66 (0.18)	1.46 (0.64)	5.33 (4.32)	3.87 (3.94)

Table 3. Average distance moved from nest, estimates of incubation range (50, 75, 95% kernels in hectares) and recess movement range (95% kernel in ha for all locations not falling within the 75% kernel for incubation range) for nesting Rio Grande wild turkeys in north-central Texas, USA during 2012-2013.

Vegetation Classes	Mean nest cover height (m)	Mean nest cover diameter (m)
Woody (n = 36)	2.25 (SE = 1.70; range = 0.61 - 6.10)	2.10 (SE = 1.44; range = 0.61 - 4.57)
Grasses (n = 6)	0.70 (SE = 0.23; range = 0.61 - 1.22)	2.34 (SE = 2.05); range = 0.30 - 6.10)
Forbs (n = 4)	1.14 (SE = 0.29; range = 0.91 - 1.52)	2.44 (SE = 2.00; range = 0.61 - 4.57)
Total (n = 46)	1.36 (SE = 0.80)	2.29 (SE = 0.17)

Table 4. Nest-site specific vegetation measurements of Rio Grande wild turkey nests in north-central Texas, USA during 2012-2013.

Band ID	Days of Pre-nest	Nest Success/Fail	Nest within pre-nest UD (range size in ha)			Mean distance (meters from nest) (SD)	Minimum distance to nest during prenesting (meters from nest)	Day closest to nest (days before laying)
			50%	95%	99%			
8058	45	F	In (99.44)	In (599.71)	In (859.53)	385.82 (292.10)	6.47	3
A587('12)	33	F	Out (164.28)	Out (592.93)	Out (2760.9)	1149.99 (496.98)	355.37	18
A587('13)	36	F	Out (55.28)	In (850.06)	In (1347.6)	672.81 (419.41)	32.06	5
A590	45	F	Out (62.74)	In (669.23)	In (1121.2)	586.05 (430.03)	52.30	30
8009	44	F	Out (1170.7)	In (5437.83)	In (7461.24)	3267.51 (1459.30)	368.22	2
8013	45	F	Out (198.69)	In (920.86)	In (1338.1)	1931.40 (565.44)	24.07	2
8016	45	F	Out (102.96)	In (673.65)	In (1061.6)	829.89 (382.81)	30.22	7
8021	46	F	In (165.44)	In (597.1)	In (788.68)	755.88 (398.89)	3.51	2
8024	44	F	Out (169.19)	In (649.88)	In (852.21)	719.25 (501.32)	64.88	13
8026	45	F	Out (143.73)	In (595.19)	In (812.9)	689.30 (320.36)	109.37	12
8028	46	F	Out (178.09)	In (983.36)	In (1390)	1238.30 (598.61)	185.07	3
8029	43	F	In (1437.05)	In (3237.7)	In (20417.14)	6859.76 (4249.15)	36.04	12
21270	39	F	Out (299.19)	In (1772)	In (2780.9)	1149.74 (906.23)	24.03	2
8061	45	F	In (1844.2)	In (16251.03)	In (24134.74)	3452.15 (5812.75)	88.56	33
8063	45	F	Out (125.97)	In (1177.8)	In (1630.4)	3398.78 (1489.65)	2.77	2
8503	44	F	Out (72.38)	In (414.46)	In (619.38)	893.82 (470.09)	2.51	2
A588	45	S	Out (105.93)	In (520.24)	In (783.02)	702.86 (488.21)	29.73	4
A589	25	F	Out (60.97)	Out (291.09)	Out (447.92)	1301.07 (428.38)	662.18	3
A591	45	S	Out (116.69)	In (590.77)	In (924.31)	706.44 (456.13)	18.93	1
8134	41	F	Out (85.6)	In (625.05)	In (1036.4)	1563.82 (642.83)	139.50	3
8094	44	F	Out (104.99)	Out (658.12)	Out (971.9)	2102.48 (395.29)	1259.96	1
Mean	42.38		81% (Out)	14% (Out)	14% (Out)	1636.04	166.46	7.62
SD	5.21					1523.96	299.34	9.23

Table 5. Average and minimum distance moved from nest during the pre-nesting period for nesting Rio Grande wild turkeys in north-central Texas, USA during 2012-2013.

Band ID	Days of Pre-nest	Nest Success/Fail	Nest within pre-nest UD (range size in ha)			Mean distance (meters from nest) (SD)	Minimum distance to nest during pre-nesting (meters from nest)	Day closest to nest (days before laying)
			50%	95%	99%			
48	45	F	Out (157.44)	Out (1251.9)	Out (1506.5)	4231.81 (1283.99)	1359.08	3
50	45	F	Out (49.17)	In (427)	In (846.64)	384.35 (495.99)	31.04	6
51	46	F	Out (510.94)	In (3217.7)	In (4681)	4315.20 (2742.93)	156.31	4
132	45	F	In (429.72)	In (2050.2)	In (2846.2)	1890.91 (1986.24)	34.48	5
133	45	F	Out (115.05)	Out (433.37)	Out (603.28)	1210.52 (552.76)	367.19	5
134	45	F	Out (162.96)	Out (1109.5)	In (1610.6)	4502.91 (1550.50)	83.75	1
135	45	F	Out (489.29)	In (2347.9)	In (3573)	3424.63 (2359.39)	99.34	8
136	45	F	Out (230.73)	In (1079.8)	In (1556.1)	1349.59 (751.92)	192.39	7
369	45	F	In (341.75)	In (1625.8)	In (2235.4)	1101.39 (1132.95)	51.12	2
371	45	F	Out (274.24)	Out (1213.1)	In (1850.5)	1535.42 (734.1937)	503.43	9
372	45	F	Out (275.82)	In (1078.8)	In (1460.8)	1157.97 (701.54)	40.03	29
656	45	F	Out (532.92)	In (2090.1)	In (2790.9)	1678.61 (832.08)	4.95	2
657	45	F	Out (69.67)	In (610.64)	In (939.36)	778.53 (593.07)	112.53	1
658	45	F	Out (124.62)	In (757.84)	In (1084.3)	1259.55 (419.53)	205.37	7
660	45	F	In (269.76)	In (1010.6)	In (1409.7)	668.63 (378.85)	53.29	32
661	45	F	Out (85.32)	In (673.81)	In (1135.1)	1464.33 (513.21)	51.07	1
662	45	S	Out (36.99)	Out (284.86)	Out (423.65)	1511.46 (315.58)	824.96	44
663	45	F	Out (114.97)	In (849.53)	In (1305.7)	4208.09 (1408.03)	175.35	4
667	45	F	Out (311.37)	In (2012.5)	In (3008.9)	1626.79 (676.84)	112.42	44
710	45	F	Out (43.78)	Out (363.07)	In (620.35)	1904.47 (544.77)	86.46	2
777	45	F	Out (73.36)	In (380.65)	In (522.73)	621.78 (386.48)	<1	5
13210	45	F	Out (155.37)	Out (650.39)	Out (899.11)	1957.31 (645.75)	816.38	41
13181	45	S	Out (115.95)	In (694.57)	In (1045)	1776.36 (713.76)	73.90	4
Mean	45.04		87% (Out)	30% (Out)	13% (Out)	1937.42	235.01	11.57
SD	0.21					1267.84	337.90	14.72

Table 6. Average and minimum distance moved from nest during the pre-nesting period for nesting Eastern wild turkeys in west-central Louisiana, USA during 2014.

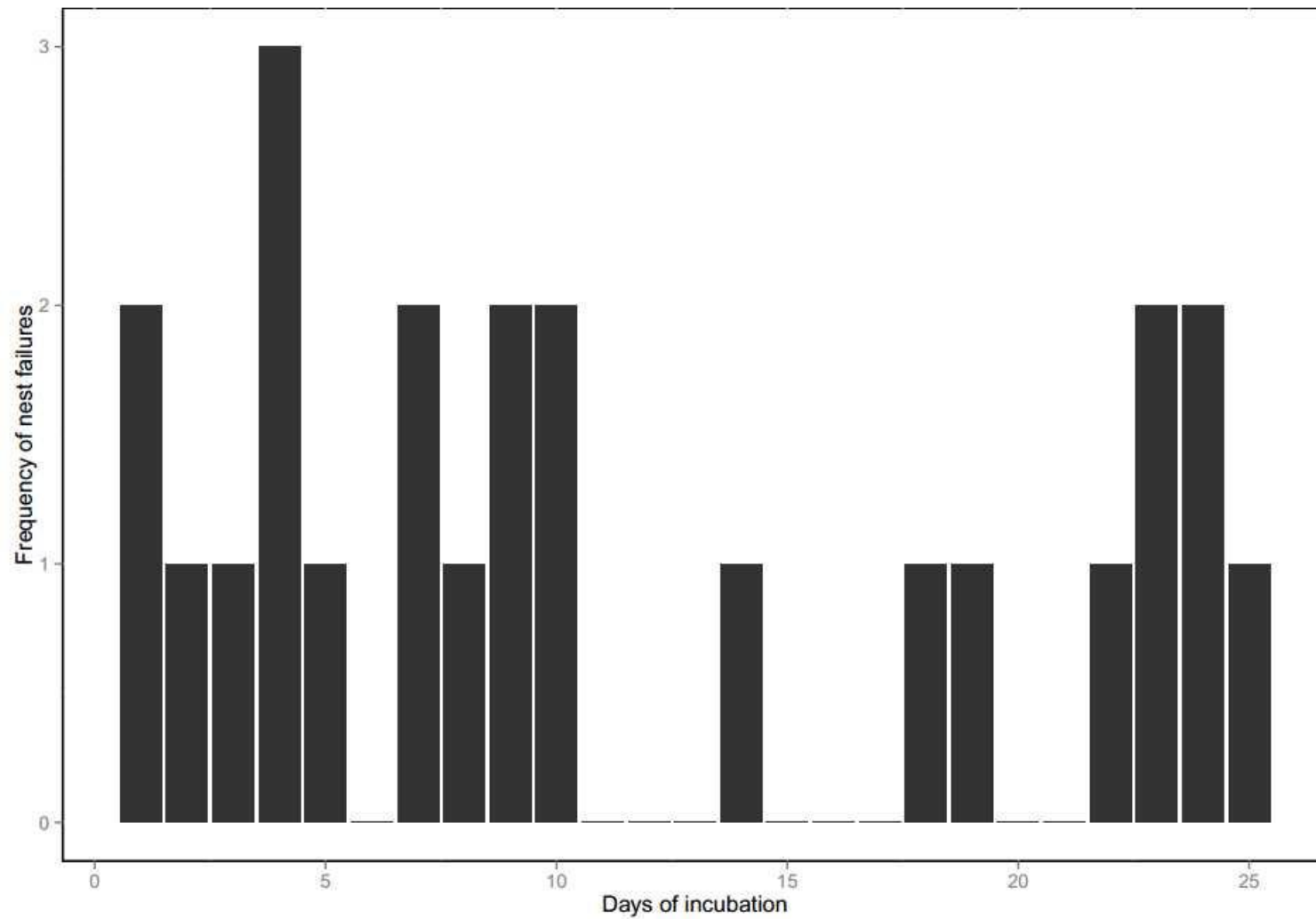


Figure 1. Nest failure frequency by day of incubation for Rio Grande wild turkey nests in north-central Texas during 2012-2013.

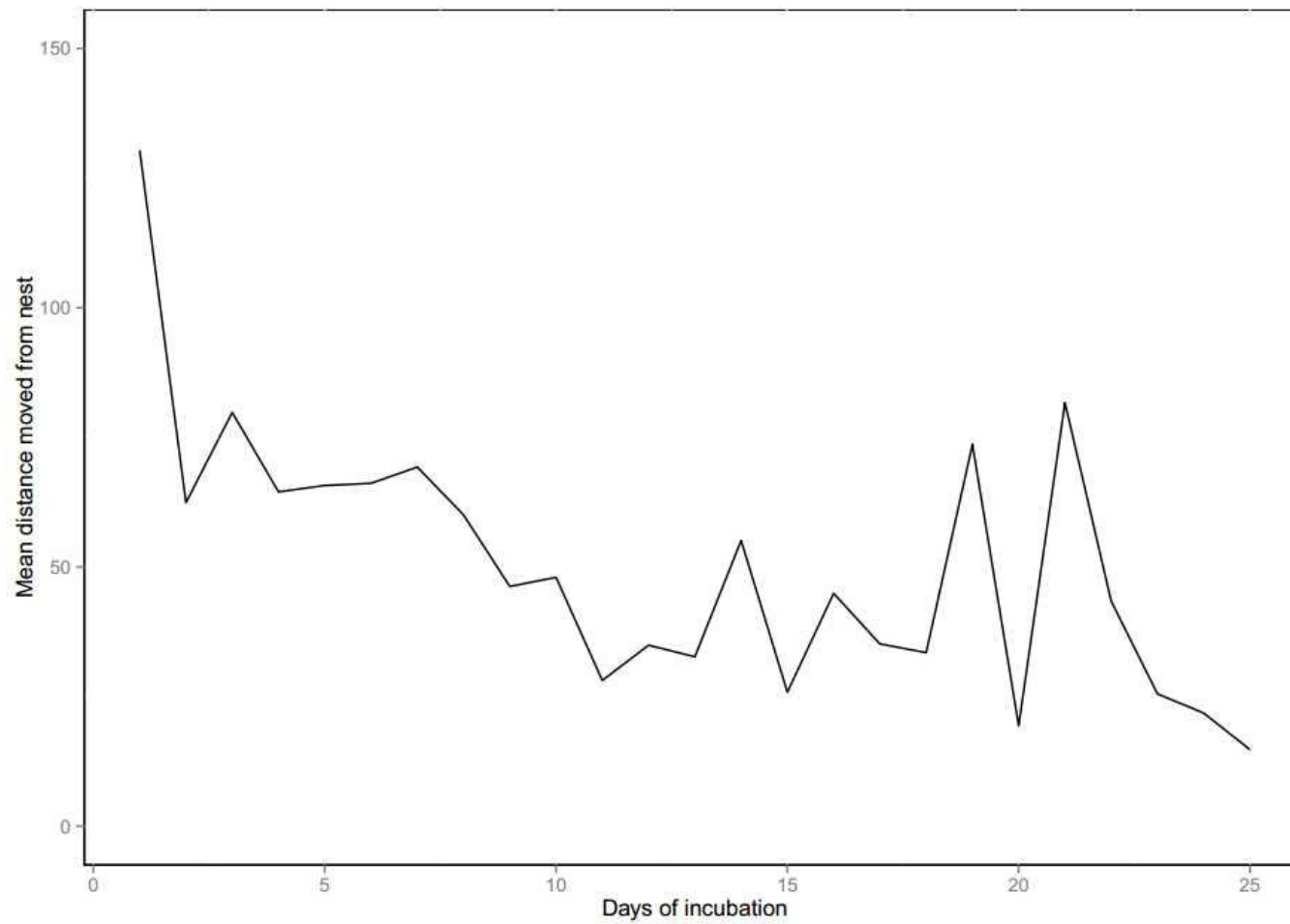


Figure 2. Mean distance (m) moved from the nest by day of incubation for 25 GPS-VHF radiotagged Rio Grande wild turkeys in north-central Texas during 2012-2013.

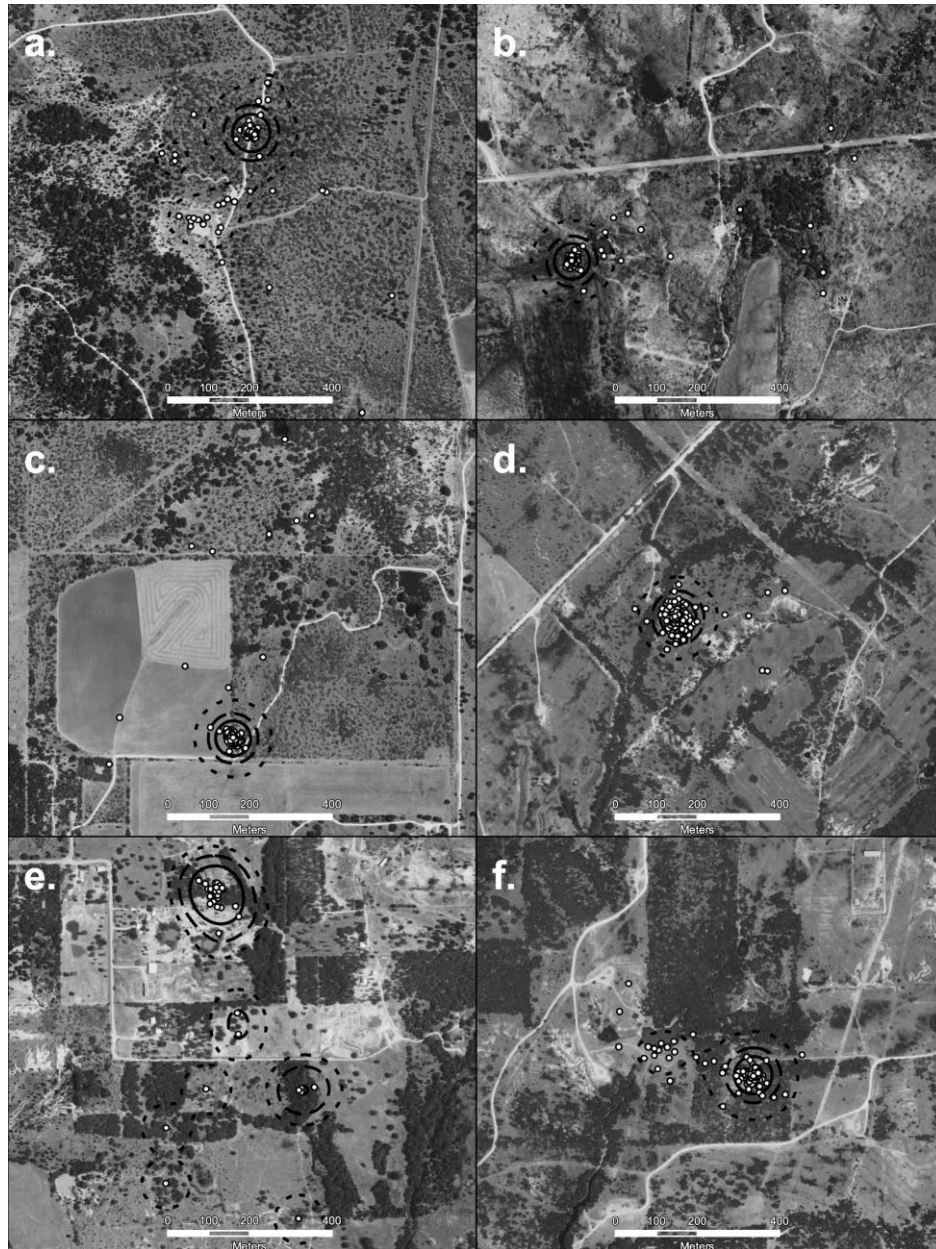


Figure 3. Incubation range 50% (solid line), 75% (large dash), and 95% (small dash) kernels for nesting Rio Grande wild turkey females in north-central Texas during 2012-2013, taking an average 30 locations per day. Females incubated for 10days before failure (Panel A), 23 days before failure (Panel B), 19 days before failure (Panel C), 24 days before hatch (Panel D), 2 days before failure (Panel E), and 18 days before failure (Panel F).

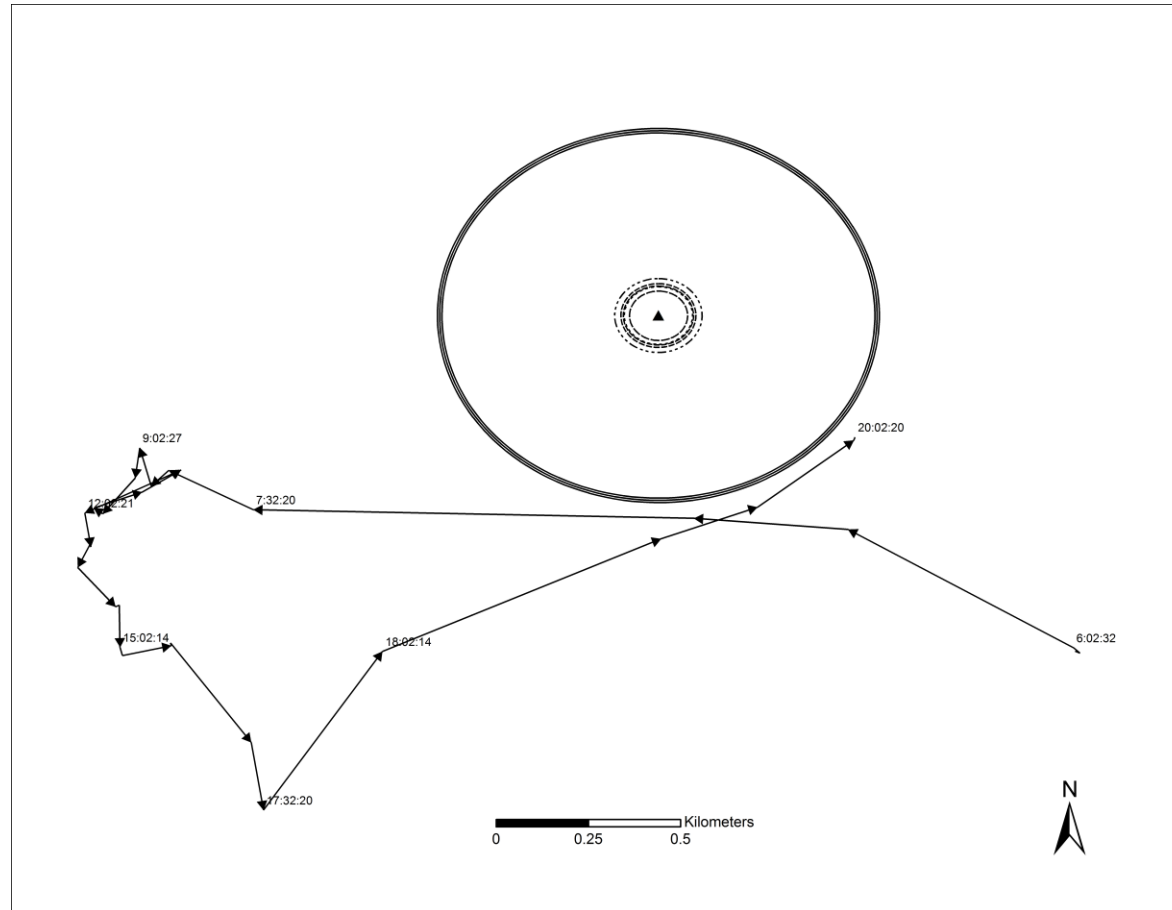


Figure 4. Example of individual-specific, nest-associated buffers showing no interaction during 1 day of movement for a Rio Grande wild turkey female relative to estimates of 1) the female's incubation range, 2) a 75% fixed kernel centered on the nest site, 3) the mean distance from the nest site, respectively, during incubation based on all females and 4) 100 and 500 m buffers around each nest site. Using these buffers, I classified each hourly path segment as either intersected (1) or non-intersected (0) for regression analysis.

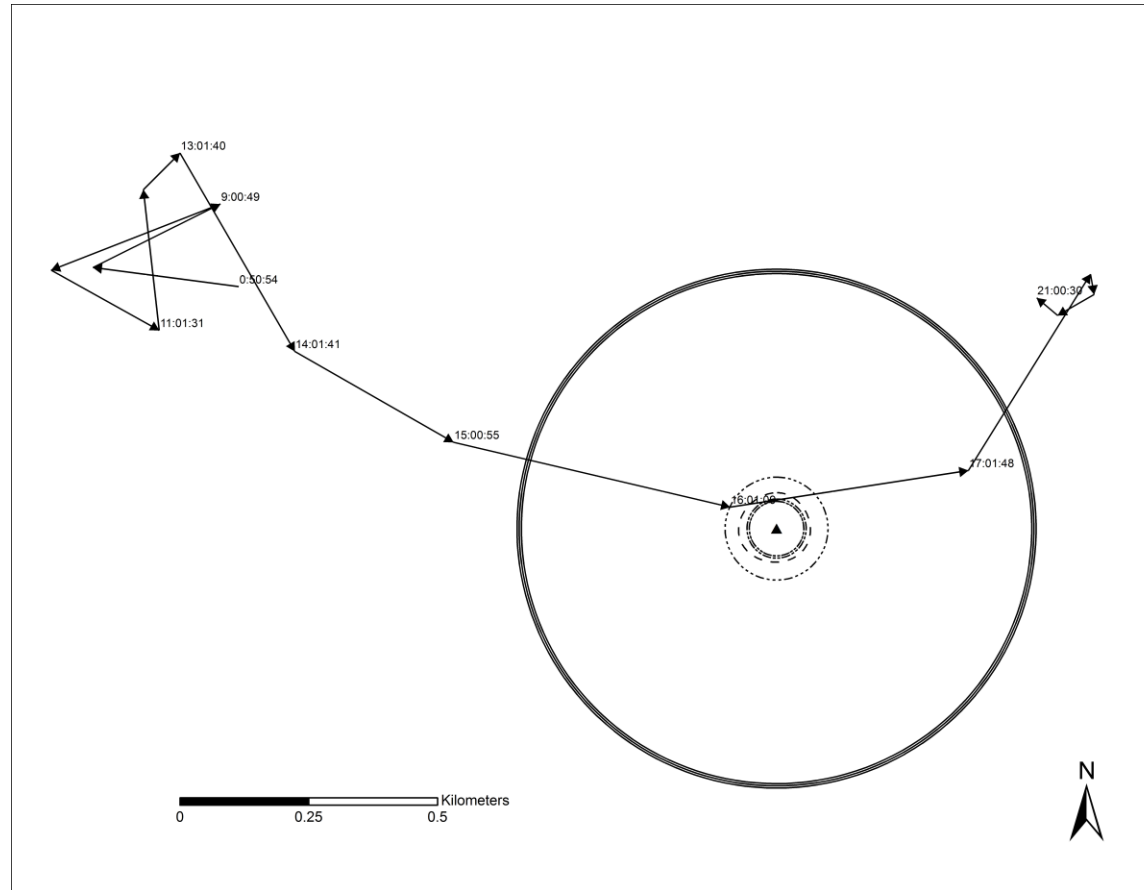


Figure 5. Example of individual-specific, nest-associated buffers showing multiple interactions during 1 day of movement for a Rio Grande wild turkey female relative to estimates of 1) the female's incubation range, 2) a 75% fixed kernel centered on the nest site, (3) the mean distance from the nest site, respectively, during incubation based on all females and 4) 100 and 500 m buffers around each nest site. Using these buffers, I classified each hourly path segment as either intersected (1) or non-intersected (0) for regression analysis.

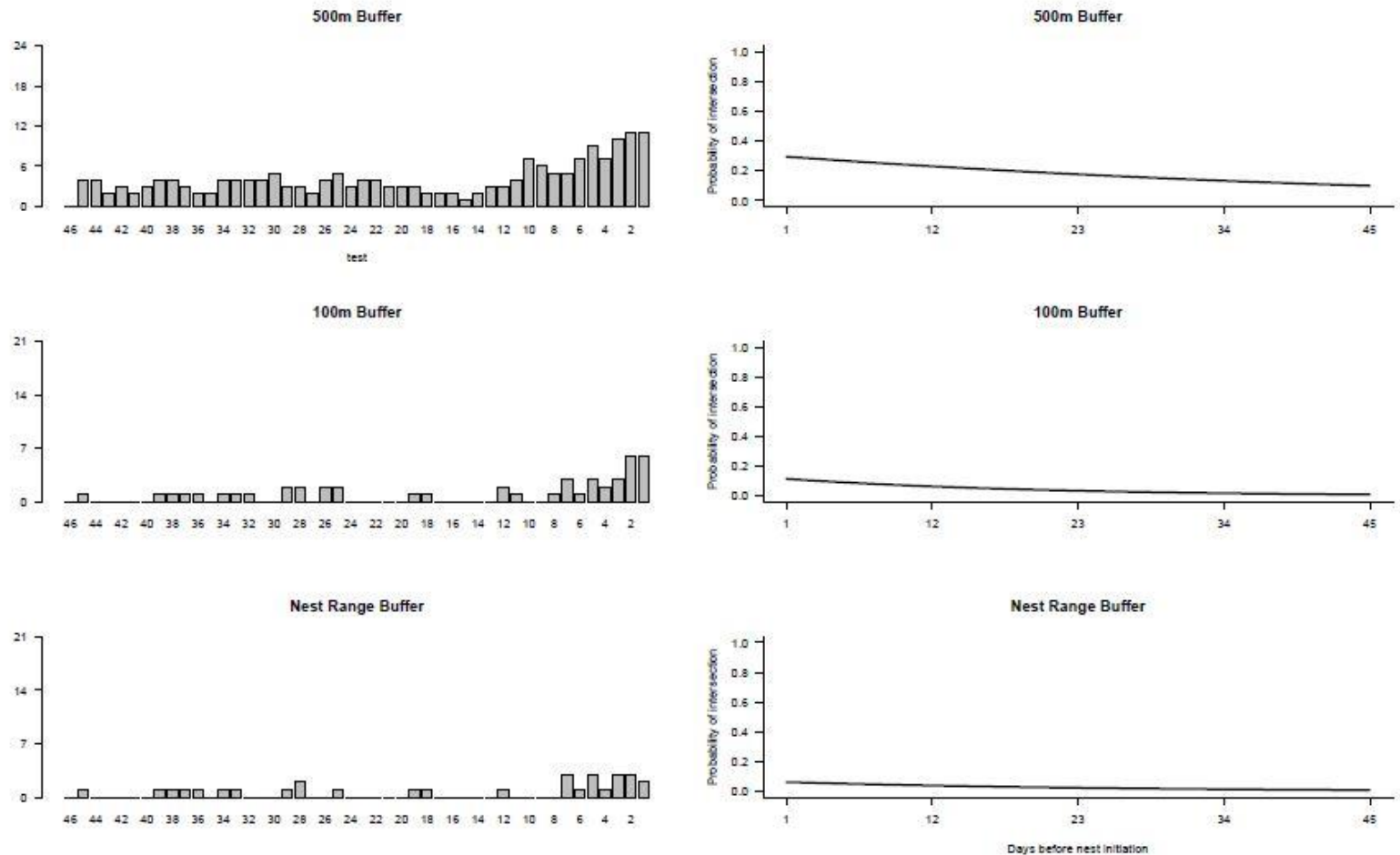


Figure 6. Left panel shows the relative frequency for Eastern wild turkey females ($n = 23$) interacting within a 500 m, 100 m, or individual specific nest range buffer relative to the number of days before laying was initiated. Right panel shows the logistic regression relationship estimating the probability that a female would be within the associated buffer size relative to days before laying began.

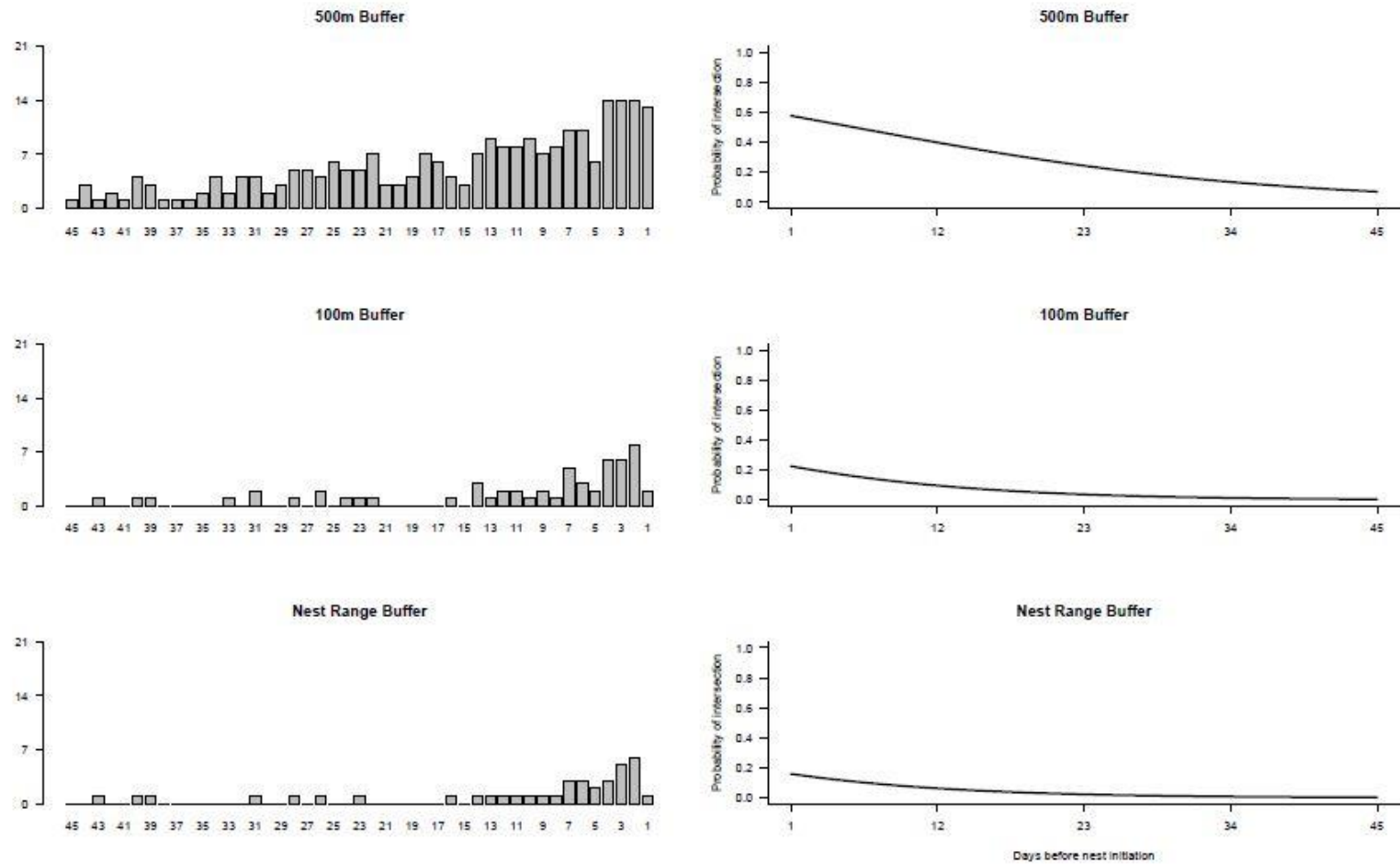


Figure 7. Left panel shows the relative frequency for Rio Grande wild turkey females ($n = 21$) interacting within a 500 m, 100 m, or individual specific nest range buffer relative to the number of days before laying was initiated. Right panel shows the logistic regression relationship estimating the probability that a female would be within the associated buffer size relative to days before laying began.